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Symptomatic epiphyseal sprains and stress fractures of the finger phalanges in adolescent sport climbers

Entorses symptomatiques et fractures de stress épiphysaires des phalanges de la main chez les jeunes grimpeurs

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Abstract

The purpose of this study was to document and evaluate patient characteristics, injury mechanisms and clinical outcomes of epiphyseal stress fractures of the finger phalanges in adolescent rock climbers to identify contributing factors to this injury. Twenty-eight climbers with epiphyseal pain treated at our clinic between 2006 and 2018 were included in the study. Sixteen patients completed a questionnaire addressing injury details as well as training regimen before and after the injury.

The mean age at the time of injury was 13.7 years (± 1.9 years) with the injury occurring predominantly in male athletes. Middle (58%) and ring (30%) fingers were the most commonly affected sites out of a total of 67 fingers affected; 54% had a radiologically documented epiphyseal fracture (Salter Harris type II/III) while 46% suffered from a symptomatic sprain, which could potentially lead to a stress fracture. Mean time for radiological union of a fracture was 35 weeks. Recovery time for a symptomatic sprain was on average slightly shorter at 24 weeks. All patients were treated conservatively with load reduction for 3–12 months until the symptoms disappeared.

Although most patients had a positive outcome when treated correctly, this injury can damage the growth plate when left untreated, resulting in articular surface incongruency (1 severe, 1 moderate, 6 mild) with permanent impairment of the affected finger. Therefore, pain on the dorsal aspect of the proximal interphalangeal joint in adolescent climbers must be assessed carefully.

Résumé

Les objectifs de l'étude étaient de documenter et d'évaluer les caractéristiques des sujets, le mécanisme de lésion et les résultats cliniques des fractures de stress épiphysaires des phalanges de la main chez les jeunes grimpeurs afin d'identifier les facteurs pouvant contribuer à cette blessure. Nous avons inclus 28 grimpeurs souffrant de douleurs

épiphysaires qui ont été traités dans notre clinique entre 2006 et 2018. Seize d'entre eux ont rempli un questionnaire portant sur les détails de la blessure ainsi que sur leur entrainement avant et après la blessure.

L'âge moyen au moment de la blessure était de 13,7 ans (+/- 1,9) et la blessure a été principalement observée chez les sujets masculins. Le majeur (58%) et l'annulaire (30%) se sont avérés être les doigts les plus touchés, avec un total de 67 blessures observées ; 54% d'entre eux souffraient d'une fracture épiphysaire (de type Salter-Harris II/III) identifiée par radiographie, tandis que les 46% restants présentaient une entorse symptomatique, pouvant potentiellement évoluer en fracture de fatigue. Le temps moyen de consolidation radiologique d'une fracture était de 35 semaines et le temps de récupération pour une entorse était sensiblement plus court (24 semaines en moyenne). Tous les patients ont été traités orthopédiquement avec une réduction des sollicitations pendant 3 à 12 mois jusqu'à l'absence de symptômes.

Si la plupart des patients ont eu des résultats positifs après des traitements adéquats, cette blessure peut endommager la plaque de croissance si aucun traitement n'est appliqué et il peut en résulter une incongruence articulaire (1 grave, 1 modérée, 6 cas légères) avec des conséquences permanentes pour le doigt atteint. Par conséquent, les douleurs sur la face dorsale de l'articulation interphalangienne proximale chez les jeunes grimpeurs doivent être examinées avec attention.

Keywords: Epiphyseal fracture; Proximal interphalangeal joint; Finger injury; Climbing
Mots clés: Fracture épiphysaire ; Articulation interphalangienne proximale ; Blessure des doigts ; Escalade sportive

1. Introduction

Epiphyseal stress fractures of the finger phalanges have become the most common injury among adolescent sport climbers [1-5]. This climbing-specific injury was first described by Hochholzer et al. in 1997 [3] and later by Chell et al. in 1999 [4]. The most frequent fracture pattern is Salter-Harris type III at the dorsal aspect of the middle phalanx, mostly affecting the middle or ring finger [6,7]. Due to the increasing popularity of sport climbing, especially on a competitive level, vigorous training is often initiated at an early age when skeletal growth of the athletes is still on-going. Training methods often involve intense finger strengthening exercises associated with heavy loads on the finger joints [8,9] which bear an increased risk for epiphyseal damage. Schöffl et al. identified regional differences the injury prevalence and postulated a direct link to training-specific methods [10].

Epiphyseal stress fractures of the finger joints are a relatively unknown injury among physicians who are unfamiliar with climbing. To date, little research in this field has been conducted [3-7,11,12]. Early diagnosis as well as strict rest from climbing supported by functional therapy contributes to a positive outcome. Delayed diagnosis can result in malunion with deformity or disabling chronic pain [6,7]. In view of this growing clinical concern, increased awareness and understanding of this injury is needed to optimize training strategies and reduce long-term injuries in young athletes.

The purpose of this study was to document and evaluate patient characteristics, injury mechanisms and clinical outcomes in order to identify contributing factors for epiphyseal stress fractures among adolescent climbers.

2. Patients and methods

2.1. Patients

All climbers treated by the senior author (AS) between 2006 and 2018 who suffered an epiphyseal injury of the finger phalanges were included in this study. The study population was comprised not only of patients with radiologically documented stress fractures, but also patients who had pain over the base of the dorsal aspect of the middle phalanx. If not treated

correctly, patients with this pain profile were observed to suffer fractures later on (Fig. 1). Exclusion criteria were other finger injuries at the same time or a follow-up of less than 6 months with yet undetermined outcome.

2.2. Methods

A questionnaire was designed to determine the contributing factors and outcomes of this type of injury. The questionnaire contained 34 items addressing characteristics of the study population, injury details as well as training regimen before and after the injury. This questionnaire was filled out retrospectively by 16 study patients (Annexes 1 and 2). Informed written consent was obtained from all patients who completed the questionnaire.

Plain radiographs were obtained from all patients and, from 2012 onward, fluoroscopy was used to perform oblique views. These additional views were obtained because, in our experience, the fracture line often has an oblique orientation and is not visible on ordinary AP and lateral views (Fig. 2). All patients were treated conservatively with load reduction and were advised to climb only easy routes without using a crimp grip (Fig. 3). No restrictions were placed on daily activities. Follow-up radiographs were performed at 2 to 3-month intervals until symptoms disappeared and/or radiological union of the fracture was achieved. If union was not clearly visible on plain radiograph, an additional CT-scan was performed.

The study was reviewed and approved by the Cantonal Ethics Committee of Zurich.

2.3. Statistics

A statistical analysis was performed to compute the mean and standard deviations of continuous variables. Additionally, categorical items were described by their counts. Descriptive analysis was performed using SPSS Statistics for Windows (Version 25.0. IBM Corp. Armonk, NY).

3. Results

A total of 28 patients (7 female, 21 males) with a mean age of 13.7 years (± 1.9 years) at the time of injury were treated during the 12-year period. Sixteen patients (3 females, 13 males) completed a questionnaire focused on injury details and training regimen; medical records only were available for the remaining 12 patients (Table 1). Half the patients (50%) had more than one affected finger. In total, 67 fingers were affected. Most cases were reported in the middle finger (58.2%), followed by the ring finger (29.9%); in few cases the little (9%) and index fingers (3%) were affected. In one patient, all fingers with exception of the thumb were affected. The injury occurred exclusively in the proximal interphalangeal joint (PIP) with the exception of one case where the distal interphalangeal joint (DIP) was affected.

Based on the questionnaire, most patients experienced an insidious onset of pain during or after climbing and none of the patients recalled a single traumatic event. Only three patients reported pain during activities of daily living prior to treatment. When asked about their training habits, nearly half the patients (43.7%) included campus board exercises and one fourth of patients (25%) trained specifically on small holds. The time between first onset of symptoms and consultation of a physician varied between 2 and 3 months (78 ± 66 days), although some patients waited over 6 months. Fifty-six percent of the patients rested completely during treatment period and 44% of the patients reduced their maximum loading by avoiding small holds or painful grip positions. Five patients (31.3%) used tape for extra support. Treatment duration ranged from 1 month to more than 6 months; the treatment lasted 2–6 months for most patients (68.8%). The majority of patients (94%) took part in climbing competitions prior to their injury with a clear emphasis on lead climbing and/or bouldering. All patients had a climbing level of at least VIII− on the UIAA scale (I [Min.] – XII [Max.], https://en.wikipedia.org/wiki/Grade_(climbing)) and 43.8% climbed harder than IX− with 3 patients climbing above X−. Fifty percent of the patients stopped competing on a national or international level, 3 of which reported having stopped because of the injury. Most patients (75%) are still climbing on a regular basis and have regained or even exceeded their

previous level of climbing. Two-thirds (62.5%) of the patients reported no pain after treatment, while the others reported rare (25%) or occasional (12.5%) pain during or after climbing. None of the patients reported pain during activities of daily living after treatment. One patient was partially satisfied with the outcome; all the other patients were satisfied.

The mean time for union of radiologically evident fractures amounted to 35 weeks. In four cases, an additional CT scan was performed since union was not clearly visible on plain radiographs. In one case where the patient presented many months after first onset of symptoms, deformity and major incongruency of the joint was observed (Fig. 4). Recovery time from a symptomatic sprain was slightly shorter on average at 24 weeks.

4. Discussion

4.1 Epidemiology

Epiphyseal injuries of the middle phalanges have become the most common injury among adolescent sport climbers and almost 100 cases have been reported in the literature during the last 20 years [1,2,5]. The majority of subjects in our cohort were male, even though female climbers are reported to participate equally frequently in Swiss youth climbing competitions according to Swiss Alpine Federation statistics. This distribution in the injury prevalence is consistent with other studies reporting that boys were more frequently affected by this injury [6,11,13]. This is possibly due to a difference in testosterone release during puberty which impairs the mechanical stability of the epiphysis [14,15]. Moreover, the difference in estrogen levels during the adolescent growth spurt between genders causes the epiphyseal plate to fuse earlier in girls and thus ends their vulnerable period for epiphyseal injuries earlier [16,17].

4.2. Etiology and clinical findings

Stress fractures in adolescent athletes resulting from overuse syndromes have been documented in various sports [14,18,19]. None of our patients suffered an acute traumatic event, suggesting that chronic stress and microfractures are the main etiological factors of this injury, as proposed earlier [6,11,14]. The reported clinical symptoms in our study

involved a slow onset of tenderness on the dorsal aspect of the base of the middle phalanx as well as pain during crimp grips and a flexion deficit. Complaints during half-open or open finger grip positions were less frequent. Maximum flexion at the PIP joint during crimp grip positions is known to result in high compressive forces on the dorsal aspect of the epiphysis and growth plate [7]. Thus, this grip position seems to be directly linked to the injury mechanism. The most common injury site in our study was the PIP joint of the middle finger, followed by the PIP joint of the ring finger. Previous studies also reported that most epiphyseal fractures affect the middle finger [7,11,12]. This distribution is supported by a biomechanical analysis during climbing, which revealed that the most significant fingertip forces are applied by the middle finger [9]. Similarly, the middle and ring finger were found to be most commonly affected in other climbing injuries such as pulley ruptures [8,20,21]. More than one finger was injured in a remarkably high percentage of patients in our study cohort (50%).

4.3. Diagnosis

Most previous studies used conventional radiographs to diagnose epiphyseal fractures [3,4,6,12], as this is an easily applicable and cost-efficient diagnostic tool. We observed a high frequency of fractures running in an oblique plane, therefore bearing the risk of being missed on standard radiographic views. Hence, we strongly recommend additional oblique images with a conventional radiograph or fluoroscopy in patients with clinically suspected epiphyseal fractures (Fig. 2). Considering that a majority of early and mild osseous stress reactions may be undetectable on conventional radiographs, Bayer et al. proposed 3T MRI as a promising diagnostic technique for baseline assessment as well as follow-up of this injury [11]. Although MRI is very effective in showing epiphyseal stress reactions, it is not well suited to specifically quantifying the extent of epiphyseal damage or to the stage of healing after a fracture. In our experience, CT is the most accurate imaging modality to assess epiphyseal fractures. However, complex diagnostic imaging methods such as MRI or CT are much less cost-efficient and usually have no therapeutic benefit when managing this kind of injury. Therefore, we only used CT scans if union was not clearly

visible on a plain radiograph. Given that no radiological evidence of a fracture was found in almost half the symptomatic patients in our study cohort, we surmised these subjects merely suffered a symptomatic sprain. It seems that the development of an established fracture visible on an X-ray view may take several months. In conjunction with a relatively short mean period between onset of complaints and consultation at our clinic, we conclude that these patients generally presented with their injury in the early stages before it had resulted in a stress fracture. It is therefore important to follow the patients with epiphyseal pain clinically and radiologically for several months. We recommend seeing the patients every 2–3 months until the pain has disappeared, to avoid missing later development of such a stress fracture.

4.4. Treatment and outcome

Nonsurgical management of these fractures has become the standard of care. Generally good outcomes can be expected if diagnosed at an early stage [6,7]. All patients in our study cohort were treated conservatively with strict rest or reduced maximum loading, avoidance of small holds and painful grip positions. Most patients experienced complete remission of their symptoms and were even able to improve their climbing grade after treatment. The mean time for fracture union in follow-up imaging amounted to 35 weeks (3 months [Min.] – 24 months [Max.]). Recovery time for a symptomatic sprain was slightly shorter on average at 24 weeks, but within a similar range as stress fractures, with several patients taking up to 12 months to recover. Therefore, a symptomatic sprain does not necessarily result in a shorter recovery period and recurrence of symptoms is quite common if full loading is applied too early, which could subsequently result in a stress fracture. One patient suffered from epiphyseal fractures of the middle and ring finger of both hands and had a prolonged recovery period resulting in moderate joint incongruency (Fig. 5). Unfortunately, another patient presented many months after the onset of pain with severe damage and advanced osteoarthritis. Conservative treatment in this case resulted in major joint incongruency and permanent movement restriction (Fig. 3). El-Sheik et al. reported excellent outcomes in two patients with a displaced established nonunion after percutaneous spot drilling epiphysiodesis [12]; both patients were able to perform at an elite climbing level

3 months after treatment. Therefore, this surgical treatment option should be considered when fracture union has not been achieved with conservative treatment.

4.5. Risk factors

Almost all the subjects in our study cohort climbed on a competitive level with relatively high climbing performance. All patients had a climbing level of at least VIII− on the UIAA scale and completed several training sessions per week before the injury. There was an even distribution of injuries between athletes focusing on lead climbing or bouldering. This could be due to the fact that, at this young age, most climbers regularly compete in both disciplines. Most patients in our study cohort used training methods that included finger strength training prior to their injury, especially campus board exercises. These training methods put enormous strains on the finger joints. Therefore, specific instructions for finger strength training in young athletes should be mandatory for coaches working with minors. Parents and athletes should be warned of the potential risks of finger strength training by coaches, gym instructors and federation officials. Route setters need to be aware of these risks when setting competition routes for youth or training sessions and should avoid setting holds requiring a crimp grip. Climbing gyms are advised to restrict the use of certain training devices (e.g. campus board) to adolescent climbers until growth plate closure, which is usually between the age of 14–16 (earlier in girls than in boys). However, there is a wide range of ages at which the growth plates close.

4.6. Limitations

Several limitations of the study should be noted. First, only 16 out of 28 patients agreed to complete our questionnaire. In addition, the questionnaire was completed retrospectively by the patients at home and therefore these subjective results may be affected by recall bias. Second, due to the small study population, further research effort in a larger study population is required.

5. Conclusion

Most patients with an epiphyseal stress fracture of the base of the middle phalanx had a positive outcome after undergoing appropriate and timely treatment. However, when left

untreated, this injury can damage the growth plate with joint surface incongruency resulting in permanent impairment of the affected finger and sometimes even ending the athlete's climbing career. Therefore, dorsal finger pain, particularly at the PIP joint in adolescent climbers, must be assessed carefully and referral to an experienced physician should be considered at an early stage. Follow-ups should be conducted on all patients until the pain disappears, which may take several months. Applying pressure on the dorsal aspect of the base of the middle phalanx and specifically asking the athletes about pain in this region may be a sensible screening method during the adolescent growth spurt. Furthermore, it is important to raise awareness of this type of injury among general practitioners. Future training methods for youth climbers should avoid crimp grip positions and campus board training. Moreover, proper education of coaches, route setters, parents, athletes and gym owners is necessary to prevent this kind of injury.

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Figure legends

Fig. 1. Development and healing of an epiphyseal stress fracture. The patient had pain for 2 months without radiological evidence of a fracture, which was only visible at the 6-month follow-up visit. Healing of the fracture took another 6 months.

Fig. 2. Example of an oblique fracture not visible on a lateral view (A). The same patient's finger with an oblique view performed with fluoroscopy to detect the fracture line (B).

Fig. 3. Crimp grip position with fully flexed PIP joint and hyperextended DIP joint.

Fig. 4. Major incongruency of the joint surface and advanced osteoarthritis after delayed treatment.

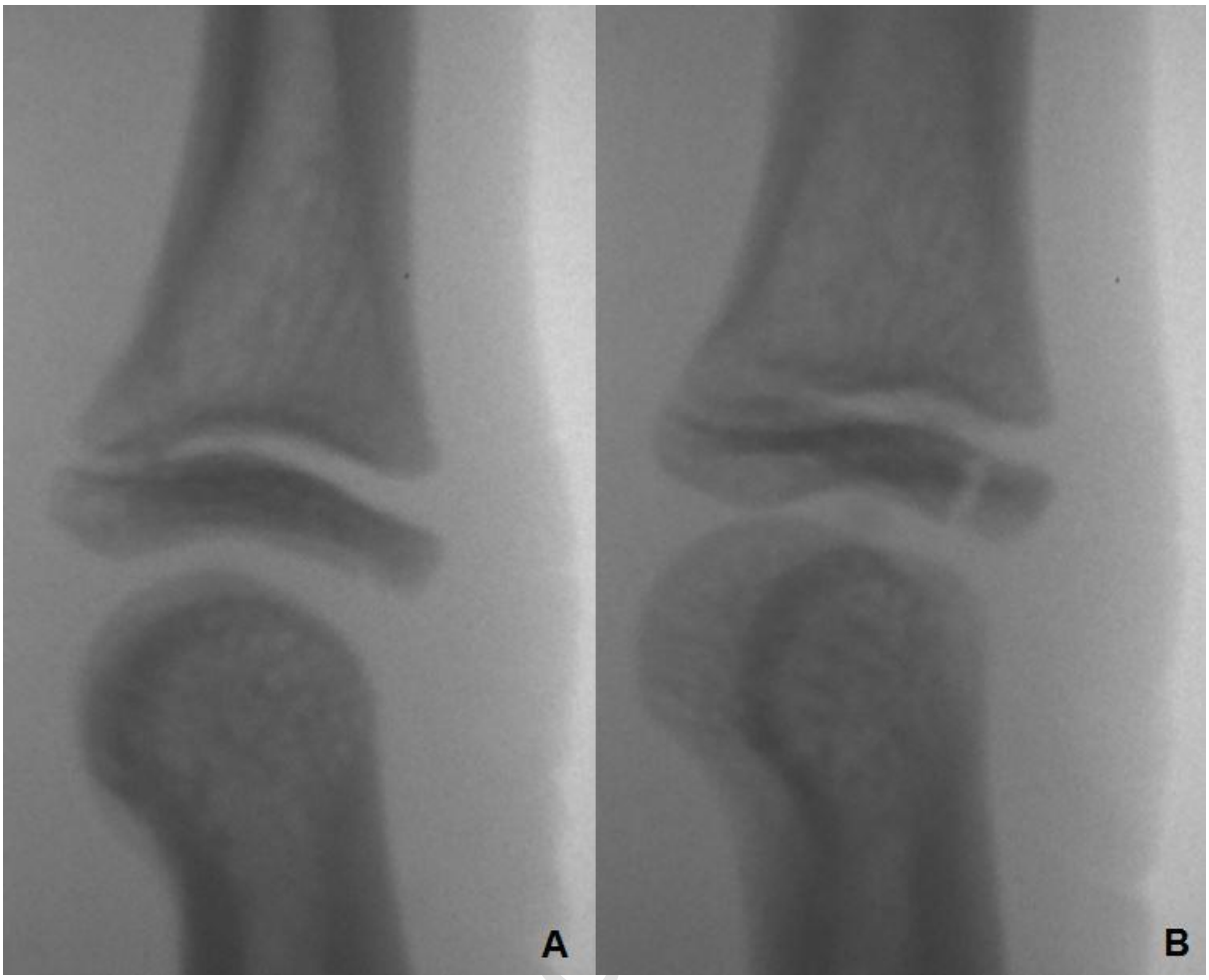
Fig. 5. Moderate incongruency and subchondral cyst (likely intraosseous ganglion as a sign of instability) after prolonged fracture union period.

Table titles

Table 1. Summary of data on injury location and radiological and/or clinical outcomes from all included patients. PIP: proximal interphalangeal joint; DIP: distal interphalangeal joint; 1: thumb; 2: index; 3: middle finger; 4: ring finger; 5: little finger; L: left; R: right; ADL: activities of daily living; *Patients who completed our questionnaire

Figr-1

Figr-2



Figr-3

Figr-4

Figr-5

Age	Gender	Diagnosis	Location (joint, finger, side)	Radiological outcome	Union time [months]	Clinical Outcome
13	Male	Fracture	PIP 3 L+R	Minor Inc.	11	Complete functional recovery
13	Male	Fracture	PIP 3 R	Complete	6	Complete functional recovery
13	Female	Fracture	PIP 3 L	Complete	3.5	Complete functional recovery
13	Male	Fracture	PIP 3 L+R	Minor Inc.	8.5	Complete functional recovery
13	Female	Fracture	PIP 3 R	Complete	5	Complete functional recovery
***13**	Male	Fracture	PIP 3 R	Complete	4	Complete functional recovery
***14**	Male	Fracture	PIP 3 L	Minor Inc.	9.5	Complete functional recovery
***14**	Male	Fracture	PIP 3 L	Minor Inc.	10	Complete functional recovery
***14**	Male	Fracture	PIP 3 R	Complete	6.5	Rare pain after climbing
14	Male	Fracture	PIP 3/4 L+R	Moderate Inc.	24	Complete functional recovery
***15**	Male	Fracture	PIP 4 R	Minor Inc.	14	Complete functional recovery
***15**	Male	Fracture	PIP 3 L+R	Minor Inc.	12	Stopped climbing because of injury, no pain during ADLs
***16**	Female	Fracture	PIP 3 R	Major Inc.	n/a	Stopped climbing because of injury, no pain during ADLs
***16**	Male	Fracture	PIP 3 L	Complete	5	Complete functional recovery
***16**	Male	Fracture	PIP 3 R	Complete	3	Complete functional recovery
10	Female	Symptomatic sprain	PIP 4 L	n/a	n/a	Complete functional recovery
11	Male	Symptomatic sprain	PIP 3/4 L+R	n/a	n/a	Complete functional recovery
***12**	Male	Symptomatic sprain	PIP 3 L+R, 4 R	n/a	n/a	Complete functional recovery
***12**	Male	Symptomatic sprain	PIP 3/4 L	n/a	n/a	Rare pain after climbing
13	Male	Symptomatic sprain	PIP 3 L	n/a	n/a	Complete functional recovery
***13**	Female	Symptomatic sprain	PIP 2-5 L+R	n/a	n/a	Rare pain during or after climbing
14	Female	Symptomatic sprain	PIP 3-5 L+R	n/a	n/a	Complete functional recovery
***15**	Male	Symptomatic sprain	PIP 3/4 L+R	n/a	n/a	Complete functional recovery
16	Male	Symptomatic sprain	PIP 3 L+R	n/a	n/a	Complete functional recovery
***16**	Male	Symptomatic sprain	PIP 3/4 L+R	n/a	n/a	Rare pain during or after climbing
***16**	Male	Symptomatic sprain	PIP 3/4 L+R	n/a	n/a	Complete functional recovery
***17**	Female	Symptomatic sprain	PIP 3 L	n/a	n/a	Stopped competing because of injury, occasional pain after climbing

18	Male	Symptomatic sprain	PIP 3-5 L+R	n/a	n/a	Complete functional recovery

Table 1. Summary of data on injury location and radiological and/or clinical outcomes from all included patients. PIP: proximal interphalangeal joint; DIP: distal interphalangeal joint; 1: thumb; 2: index; 3: middle finger; 4: ring finger; 5: little finger; L: left; R: right; ADL: activities of daily living; *Patients who completed our questionnaire